CHAPTER 16

ELECTRICAL SERVICE INTERFERENCE

Section I-DISTURBANCE PRODUCERS

16-1. Electrical power quality.

Electrical end-users are experiencing increased problems from the expanding use of disturbance-producing electrical equipment. Most equipment served by electrical facility exterior distribution lines can tolerate short-term voltage and current variations without operational problems. The concerns discussed in this chapter are voltage and current sources which produce excessive and/or continuous electrical noise, resulting in unacceptable electric power quality. These sources may interfere with adjacent communications equipment or generate damaging waveforms, which flow back into the electrical distribution system and extend the interference.

16-2. Electromagnetic interference (EMI).

EMI occurs when undesirable electrical signals from an emitting source are transferred, by radiated or conducting media, to a receptor or receiver element. These unwanted electrical signals with their undesirable effects are known as electrical noise (designated simply as noise hereafter). EM1 includes radio interference (RI) which, as defined by the Federal Communications Commission (FCC), includes only 10 kilohertz to 300 gigahertz disturbances. The first evidence of this type of interference will usually show up as impaired radio or television set reception.

16-3. Harmonic interference.

Harmonic interference is produced by nonlinear loads which draw current discontinuously, or whose impedance varies with the applied voltage.

a. Sources. Gaseous discharge lamps and solid-state equipment, such as variable frequency drives and computers, are harmonic interference sources. The accelerated use of solid-state devices has multiplied harmonic input sources operating on residential, commercial, and industrial electrical systems.

b. Occurrence. Harmonics can be differentiated from transients, since harmonics occur as a periodic wave which contains multiples of the fundamental 60-hertz frequency and transients occur as a temporary variable of the fundamental frequency only. Harmonics have always occurred in power systems but increased use of high-level harmonic-producing equipment has made harmonic interference control a matter of general concern to both electrical power distributors and users.

Section II-ELECTROMAGNETIC INTERFERENCE

16-4. Electrical distribution system interference.

Electromagnetic interference on a power system is an avoidable problem. Such interference indicates potential line trouble, which may sooner or later cause an outage on the circuit. Distribution apparatus and devices have design features which minimize electromagnetic interference. Interferences occurring on distribution systems result from poor quality workmanship or maintenance. Loose connections, inadequate grounding and bonding, and even the location of staples securing the ground wire to the pole are possible sources of EMI. Defective or improperly adjusted apparatus can add to the trouble. Do not wait until a complaint comes in before taking action. Be alert to the problems associated with electromagnetic interference, so that noise developing on the system can be detected and eliminated during regular system surveillance. Additional information on this subject can be found in NAVFAC MO-202.

16-5. Electrical noise origin.

Noise generated by EMI originates from two sources: electric distribution power lines and premises wiring (residential, commercial, or industrial). Noise is caused by defective installations of premises utilization equipment and wiring or by faulty construction of the exterior electric distribution system.

a. Utilization equipment noise. Utilization equipment noise can easily be isolated in a building by disconnecting suspected equipment, item by item, and listening for changes in the noise. These noises generally result from conducted interference and will affect consumers connected to a common transformer, but do not spread over the system for any great distance.

b. Noise originating on electric power lines. Electric power line noise can be attributed to three main causes. The first is defective insulation in some apparatus part; the second is loose primary or secondary connections; and the third is electrostatic leakage between ungrounded hardware and pole assembly grounded parts. Of these three causes, the third is the most common and the most difficult to locate and will be treated in the most detail.

(1) To locate noise from the first two causes, items of line equipment should be examined for the following defects:

(a) Loose hot-line clamps.

(b) Corroded fuse ferrules in cutout boxes.

(c) Defective surge arresters (particularly the gapped valve type).

(d) Defective insulators and transformer bushings.

(e) Defects in the internal insulation of a transformer.

(f) Loose connections in a neutral circuit.

(g) Loose ties on insulators and neutral brackets.

(h) Covered tie wire used on a bare conductor.

(i) Loose pole-line hardware.

(j) Insufficient spacing between grounded and ungrounded parts of pole assembly. Spacing should be 2 inches (51 millimeters) minimum for 7.2 kilovolts and 8 inches (204 millimeters) minimum for 14.4 kilovolts.

(2) Noise from electrostatic leakage is most commonly found on a multigrounded neutral type of circuit and is the most difficult to trace. Noise which originates on the primary, due to leaky insulators and the like, generally dies out within a few spans and is easily found. Noise which arises from electrostatic leakage and gets into the neutral circuit may, under some conditions, be detectable for 10 miles (16 kilometers) on each side of the source. This noise is caused by arcing due to insufficient spacing between some item of ungrounded hardware, within the electrostatic field of the primary conductors, and some part of the grounded pole assembly.

(3) It is important to recognize that any piece of pole-line hardware, which is near an energized conductor, may pick up enough electrostatic charge to spill over a small gap. Cases of interference have been traced to long lengths of barbed wire fencing running for some distance under a power line before discharging to ground. In one case the entire fence acted as an antenna and transferred the noise back into the primary. This noise was detectable for 5 miles (8 kilometers) from the source on an automobile receiver. For construction in progress, conductors should be tied in on insulators and all wires should be grounded to the system neutral at several points to prevent possible interference and also to serve as a safety precaution. This precaution also applies to telephone system construction which has not reached the stage where drainage coils have been installed. Ungrounded conductors on construction in progress, as well as ungrounded hardware on the pole assembly, should be treated with the same care and precautions as energized conductors. The minimum spacing (given earlier) should be maintained between all ungrounded pole assemblies.

(4) One type of leakage noise, which is common and puzzling, comes from staples on the pole ground. In some cases staples are driven too near the crossarm through bolt. If the gap is small enough between the staple points and the through bolt, a leakage discharge occurs. Capacitance between the through bolt and the phase wire, and its associated tie wires, develops an electrostatic charge during each half cycle of the supply frequency to produce a square wave with 120-hertz frequency. The electrical interference from this wave is generally most noticeable at radio frequencies near 800-kilohertz, although harmonics present from the 120-hertz square wave shape can cause interference up to the l00-megahertz region of the radio frequency spectrum. Line attenuation generally reduces the higher megahertz frequency harmonics, so that they do not spread as far as harmonics in the broadcast band. Taps tune the noise signal, so that some noise frequencies are damped out while others are accentuated. The discharge gap length influences the striking voltage of the arc and the width of the square wave, which is related to the fundamental frequency of the noise signal. If the noise wave is examined on an oscilloscope, it appears as a small spike on the tip of each half cycle of the 60-hertz power wave.

(a) Leakage noise occurs in a similar manner when ungrounded crossarm braces are too close to ground wire or grounded guys, and when neutral ground wires are too close to phase-wire pins on crossarms. Fuse-cutout brackets'and surge-arrester brackets generate leakage noise if they are too close to grounded pole members. Weatherproof wire used for the pole ground lead may cause trouble if the staples break the insulation but do not make solid contact with the copper ground wire conductor.

(b) In older construction, where a neutral conductor is carried on a metal bracket instead of on an insulator, EM1 may be created and be difficult to locate. A loose tie on one of these brackets, even though the bracket and its bolt are not grounded at the pole in question, causes the development of a noise signal which will travel over three or four spans. A multiplicity of these noise signals can blanket a wide area. Tightening these ties eliminates the noise for a short period until conductor vibration loosens the ties again. The permanent cure for this type of noise is changing insulators brackets to

those used in more modern brackets, and the use of a copper jumper with appropriate connectors for the connection to the pole ground.

(c) All connections to the neutral or to the pole ground should be made with jumper wires and connectors. This also applies to static wires used on transmission circuits. A pole ground wire placed under galvanized hardware is unsatisfactory as a ground and should not be used.

16-6. Electrical interference during bad weather conditions.

Leaky insulators generate greater EM1 when it rains as the assembly is grounded by water on and in the pole. Rain can cause other leakage noises to disappear, since the resistance of the water over the pole surface may be low enough to drain off electrostatic charges before discharge gaps can develop. In most cases, wind increases the interference level, but in a very irregular pattern. Above 50 megahertz (television frequency) noise emitted is usually very small during fair weather conditions, but will increase in bad weather.

16-7. Methods of electrical interference location.

Although there are many very good instruments available, no device has yet been invented which will unerringly locate and identify the source of EMI. The most successful method appears to be narrowing the search area and isolating suspected apparatus. Success in locating EMI depends on the acquired skill of the operator to interpret instrument readings and to recognize possible sources of noise by characteristic sounds.

a. Sound characteristics. The intermittent noise from loose connections is most apparent on windy days, as is noise caused by tree contact with primary conductors. Electric fences have a regular popping sound, whose frequency is governed by the timing apparatus built into the electrified fence controller. Insulators and bushings generally produce a heavy, rasping buzz, while staple and hardware noise is higher pitched.

b. Instruments. Utilize a receiver (interference locator) and/or meter that measure field-strength in the audio and radio frequency range. Some interference is easily found by driving along the road with the receiver volume turned up and the receiver tuned to a position near 800 kilohertz but free of any local broadcast stations. The offending pole is easily picked out and can be examined for sources of interference (unless standing waves are present). A useful implement for the detection of loose connections is a heavy hammer for striking a suspected pole. If the receiver noise changes with the blow, the pole should be examined in detail. A slight delay between the blow and the change in receiver noise indicates that the problem is in adjacent structures.

(1) Locating problem poles is more involved when standing waves are present. A series of occurring maximums and minimums in signal strength (as the truck is driven along the line) indicates standing waves. Maximum peaks will occur at intervals of 400 to 500 feet (120 to 150 meters) for 800 kilohertz and at closer intervals for higher frequencies.

(2) When comparing the strength of signal peaks, the operator should consider the distance between the receive antenna and the electric line. Signal increases due to overhead guy wires, services, and taps should be disregarded. Comparison of signal peaks can be made more easily if the noise is tuned to the FM frequencies on the broadcast band as the signal strength increases. Since FM broadcast signals die out faster than AM broadcast signals along the electric line, this technique narrows the search area considerably. When the “hot zone” is located, taps should be momentarily disconnected while the operator listens for changes in the signal. If the noise stops, the tap should be reconnected and search should be continued from the tap. A decrease in the noise upon disconnect may mean that the transmission characteristics of the line have been affected by the removal of the tap, thereby altering the level of the signal. The noise, however, is not originating from the tap. After tap isolation has been effected, and the noise continues, each pole in the noise zone should be struck with a hammer and subjected to visual inspection. A hammer blow will not affect staple noise and some other types of interference. It will, however, show up poor connections.

16-8. Instrument requirements for checking electrical interference.

A receiver suitable for power systems should have sufficient sensitivity to detect a signal that would interfere with an automobile radio or a sensitive home receiver. It should be selective enough to isolate the noise in the broadcast band without interference from broadcast signals. It should be capable of tuning over the broadcast band in order to identify signals which are causing radio disturbances in the area. Another necessary instrument feature is the inclusion of short-wave reception up to 20 or 30 megahertz, for noise tracing at the higher frequencies as previously described. The receiver should incorporate a meter in the audio circuit to give the relative levels of noise signals. If the instrument is to be used in a truck for patrolling the line, it should be shielded so as not to pick up vehicle-generated noise such as ignition interference and tire static and it should be rugged enough to withstand the vibration of the truck. The receiver's loudspeaker must be powerful enough to produce a signal which can be clearly heard above any cab noise.

a. *Self-contained portable equipment.* A portable receiver must be used on a section of an electric line which is inaccessible to the patrol vehicle. The unit should still be tunable over a wide range of frequencies and should contain its own power supply. A portable instrument is also useful in tracing noise on secondary circuits and in facility buildings where noise may originate.

b. *Useful accessory.* A small neon lamp, taped to the end of a hot stick, is a useful accessory to probe for defective insulators and bushings. Use a NE 30 or 32 lamp with the base and resistor removed. The short wires coming out of the glass bulb should be extended in a manner similar to a television set's dipole antenna rod. Each wire should be about 0.75 inch (19 millimeters) in length. The lamp will glow within 3 to 4 feet (0.9 to 1.2 meters) of a defective insulator or bushing, depending on the severity of the interference signal. A good insulator will show no indication at from 6 to 8 inches (153 to 240 millimeters). These distances will vary with line voltage as well as with the individual lamp used.

16-9. Communication interference from electrical lines.

Loose or corroded insulators and conductor or tap connections are the major abnormal conditions occurring in power systems that cause disturbances on communication circuits. These insulator or connection conditions cause high-voltage series type power arcs on primary feeders. Series-type power arcs generate a magnetic field which may fluctuate over many miles of circuit. The inductive coupling between this field and parallel communication circuits results in noise in the communication circuits. Power-arc noise on telephone lines can usually be recognized and located by communication workers trained in this type of work.

Section III-HARMONIC INTERFERENCE

16-10. Harmonic causing devices and their effects.

Harmonic interference results when excessive nonlinear loads are connected to an electrical system.

a. *Use.* Nonlinear load producing devices used on electric power systems include static power converters, arc discharge devices, saturated magnetic devices and, to a lesser degree, rotating machines. Static electric power converters which convert ac to dc, dc to dc, dc to ac, and ac to ac, are the largest producers of nonlinear loads. Static power converters found on military installations are generally adjustable speed drives, uninterruptible power supplies, or computer work stations.

b. *Effects.* The characteristics of nonlinear loads, however, change the sinusoidal nature of the ac power current (and consequently the ac voltage drop), resulting in the flow of harmonic current into the ac power system. This current can damage capacitor banks, motors, transformers, and loadbreak devices. Protective relays may malfunction; fuses may blow erroneously; and inductive interference may develop in communications circuits. Harmonics can significantly increase power losses in distribution circuits, causing a major increase in unaccounted-for energy and operating costs.

16-11. Electric power quality responsibilities.

The facility electrical supervisor (that is the Army Director of Public Works, Navy Public Works Officer, or Air Force Base Engineer) is responsible for electrical power quality, as a part of facilities operation and maintenance responsibilities. This responsibility includes the facility electrical power distribution systems and required actions to ensure these systems will supply the standard voltage ranges given in ANSI C84.1. The electrical supervisor is not responsible for the successful and reliable operation of "high tech" electronic equipment, except in accordance with ANSI C84.1. However, to ensure overall proper operation of electrical systems, recommended harmonic distortion limits for voltages should not be exceeded. Limits are for individual harmonic distortion and for total harmonic distortion (THD). THD is defined by equation. The permitted harmonic distortion limits are given in table 16-1. These limits are the permissible maximum harmonic distortion limits for service voltage at the point of common coupling (PCC) with the user or at the building service point.

$$\mathrm{THD} = \left[\frac{\text{(Sum of the squares of the rms magnitudes of all harmonics)}^{``\prime}}{\text{(Square of the rms magnitude of the fundamental)}} \right] \times 100\% \qquad \text{(eq. 16-1)}$$

16-12. Electric power quality data.

From time to time, harmonic measurements should be taken at selected points, where a high level of harmonic distortion is suspected. Measurements indicate the system behavior, and whether harmonics levels are within the limits given in table 16-1.

a. *Measurements.* Instrument response requirements are covered in IEEE 519. The basic equipment used for harmonic analysis includes:

Table 16-1. Harmonic distortion limits[1]

Bus voltage at PCC	Individual harmonic distortion (%)	Total harmonic distortion THD (%)
69 kV and below..	3.0..	5.0
Above 69 kV thru 161 kV	1.5..	2.5
161 kV and above.. ...	1.0..	1.5

(1) Oscilloscopes
(2) Spectrum analyzers
(3) Harmonic or wave analyzers
(4) Distortion analyzers
(5) Digital harmonic measuring equipment

b. Control of power quality. Maintenance personnel are not responsible for controlling power quality beyond determining, by measurements, whether the harmonic distortion of the PCC voltage exceeds table 16-1. Verify that panelboard loads are balanced, where applicable, and check wiring and grounds. A majority of power quality problems result from loose connections and improper grounding techniques, and unbalanced loads. If correcting these deficiencies does not alleviate excessive harmonics, then harmonic mitigation measures must be developed utilizing engineering solutions beyond the scope of this manual.

16-13. Electrical distribution system interference.

AIthough harmonic mitigation is not the responsibility of the electrical supervisor, it is the supervisor's responsibility to keep informed on both the quantity and quality of electrical service available to facility users. Therefore, an awareness of apparatus actions, which may indicate unacceptable harmonic levels, is necessary to determine where more precise data should be acquired.

a. Capacitors. Capacitor impedance decreases with frequency, and a capacitor bank acts as a harmonic sink where most harmonic problems are first noticed. Fuse blowing, without any obvious reason, or a capacitor unit failure, can be signs of a possible harmonic problem. A supply system inductance, in resonance with the capacitor bank, can cause large currents and voltages to develop. When, for no obvious reason, all fuses of a capacitor bank blow, it is probably a harmonic problem. If only one fuse blows, it is probably a reasonance problem.

b. Transformers. Harmonic currents cause increase copper and eddy current losses, and harmonic voltages cause increased iron and dielectric losses and insulation stress. There can be a possibility of resonance between transformer windings and line capacitance. Increased audible noise may result.

c. Cables. Harmonics result in increased copper and dielectric losses.

d. Protective relays. A higher level of harmonics is generally required to alter relay performance, but a range of 10 to 20 percent THD may affect relay operation. In general, high fault currents are not severely distorted, since the limiting impedance is the power system. The harmonic current, which is significant in relation to load current, will be much less significant in relation to fault current. High harmonic levels can cause electromechanical relays to chatter. Distance relays will see an altered impedance setting. Excessive third harmonics can cause misoperation of ground relays.

e. Instrumentation. Harmonics can lead to erroneous positive or negative errors for induction disc relays, which are normally calibrated for the fundamental current and voltage. Distortions of less than 20 percent THD will not cause significant errors, but in harmonic-rich environments, true rms sensing is needed for accurate measurements.

f. Switchgear The heating effect of the higher peak value of a very distorted voltage wave can result in premature failure of the switchgear insulating system. Circuit breakers interrupt current flow at zero current and a current wave with zeros at locations other than on the fundamental sine wave can cause circuit breakers to have premature interruption and restrike. Circuit breaker blowout coils can fail to interrupt currents. Loadbreak switches, fuses, and other switching devices can be subject to the same problems.

g. Miscellaneous. Equipment not normally part of exterior electric facilities can be affected by harmonics in the following ways:

(1) *Electronic equipment.* Electronic equipment is not only a source of harmonic currents, but is prone to misoperation if not operated on its correct voltage and current waveforms.

(2) *Rotating equipment.* Rotating machinery will see increased losses, possible reduction in available torque, and (conceivably) mechanical oscillations in prime mover/generator and motor/load combinations.

(3) *Incandescent lamps are the most sensitive to increased heating effect, which can significantly shorten lamp Life.* Gaseous discharge lighting, such as high-intensity discharge and fluorescent lamps, can produce harmonics from solid-state ballast components.